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Title: **MEASUREMENTS OF THE GRIP BETWEEN A VEHICLE WHEEL AND THE ROAD**

Abstract

The tyre comprises a sacrificed rib (1) adjacent to an ordinary rib (2).

During normal operation the sacrificed rib (1) slides against the ground while the ordinary rib (2) does not slide against the ground. Thanks to the sacrificed rib (1), a measurement of the maximum grip potential on the ground at any time is made.

Fig. 1

The present invention relates to the grip of a vehicle on a roadway. More particularly, it concerns the determination of the grip characteristics of a vehicle wheel fitted with an elastic covering such as a rolling tyre, by obtaining physical parameters in the contact area between the said wheel and the surface along which it is rolling.

In this context there is a need to obtain indications "in real time" of the grip conditions that can affect the behaviour of a vehicle, notably when it is undergoing an acceleration under drive power, or when braking, or when changing direction. The purpose of the invention is to provide a method and means for achieving this in an effective way.

In what follows, the term "gripping potential of a given element" (when the said element may be a pad of rubber, the rib of a tyre, or the tyre as a whole) is used to denote the ratio between the maximum tangential force that the element can undergo during its contact with the ground, at a given place, and the normal force applied to the element. The term "friction potential" is used to denote the ratio between the tangential force and the vertical stress exerted at a given point on a rubber element sliding over the ground.

The term "available grip margin" means the difference between an element's grip potential and the ratio between the tangential force and the vertical force effectively applied to the element when it enters the contact area.

The subject of the invention is a tyre suitable for estimating the grip potential or grip margin, whose tread comprises a first tread element having an area of contact with the ground, which is positioned a distance from the wheel axle smaller than that of at least one second element, the said elements being such that in normal operation their surfaces come into contact with the ground within the contact area, and also being such that, at least within a range of rolling conditions to be monitored, the contact surface of the first element slides relative to the ground during its passage through the contact area. The said tyre also comprises means constituting a sensor within the said first element, and the means that constitute a sensor are sensitive at least to a tangential force in the said contact surface of the said first element, during the passage thereof through the contact area.

The invention therefore proposes to adapt part of the tread so that it exceeds its grip limit, and to make at least one appropriate measurement in that part. Sensors may be integrated into the tread as stated above, but the appropriate measurement or measurements can also be effected without necessarily integrating sensors in the tread of the tyre.

The invention also proposes a method for detecting a grip characteristic between a wheel with a deformable tread and the ground along which it is rolling, the said method comprising the following stages:

a) Provision of at least one first contact element of the tread having an area of contact with the ground located a distance from the wheel axle smaller than the distance of the ground contact area of at least one second element, the separation between these contact areas being such that during normal operation the surfaces of the two elements both come into contact with the ground, and at least within a range of rolling conditions to be monitored, the contact surface of the first element slides relative to the ground during its passage in the contact area.
b) Production of a first signal that represents a tangential force in the said contact surface of the element nearest to the axle.
c) Detection of a variation of the said first signal, that characterises a loss of grip.
d) Production of an estimate of the friction potential in the said contact surface of the said first element.
e) Production of an estimate of the tyre's grip potential.

Of course, the invention makes it possible to estimate the "available grip margin" as the difference between the tyre's grip potential and the ratio between the tangential and vertical forces effectively applied to the tyre, if the said tangential and vertical forces have been evaluated. For example, the tangential force in the longitudinal direction and the vertical force can be estimated by the means described in US 5,913,240. However, the tangential and vertical forces can also be estimated by measurements all effected within the tread. Further details on this point will be given below.

According to a variant, the invention proposes to estimate the "available grip margin" without having recourse to measurement or estimation of the vertical and tangential forces effectively applied to the tyre. For this, the invention proposes a method for detecting a grip characteristic between a wheel with a deformable tread and the ground along which it is rolling, which comprises the following stages:

a) Provision of at least one first contact element of the tread having an area of contact with the ground located a distance from the wheel axle smaller than the distance of a ground contact surface of at least one second element, the separation between these contact surfaces being such that in normal operation the surfaces of the two elements both come into contact with the ground.

b) Production of a first signal that represents a tangential force in a zone of the contact surface of the said first element.

c) Detection by virtue of the said first signal of the instant when the said first element enters the contact area.

d) Detection in the said first signal of the instant when the first signal undergoes a change that characterises a loss of grip.

e) Production of an indication characterising an available grip margin from a function of the first signal between the instant when its entry into the contact area is detected and the instant when the said characteristic change is detected.

The invention is illustrated by the following figures:

Fig. 1: Radial section of a tyre that can be used with the method according to the invention

Fig. 2: Schematic representation of the operation of a tyre

Fig. 3: Table diagram of the observations typical for the method according to the invention in an idealised case

Fig. 4: Showing the observations proposed by the invention

Fig. 5: Showing other observations proposed by the invention

Fig. 6: Showing still other observations proposed by the invention

The tyre according to the invention comprises either one or more complete ribs 1, or one or more tread-pattern pads whose outer circumference has a radius Rs smaller than the radius Ra of

the circumference of the ordinary ribs 2 or the adjacent ordinary pads (see Fig. 1).

In the remainder of this document a rib 1 or pad of this type will be called respectively a "sacrificed rib" or "sacrificed pad", or "first element". The patent US 4,480,671 shows such a sacrificed rib (see lateral rib 8). In contrast, any other portion of the tyre pattern will be called an "ordinary rib 2" or "ordinary pad", or "second element". Those familiar with the field know that the difference between Ra and Rs can automatically be maintained during the wear of the tyre in normal service. An advantage of the invention is that the available grip margin can therefore be determined until the tyre is completely worn down, thanks to a measurement of the friction potential carried out on a sacrificed rib.

The tyre so adapted makes it possible to estimate the "grip potential", a concept defined earlier and used essentially with reference to the tread as a whole. The tyre so adapted can also allow estimation of the "friction potential", a concept defined earlier and used with reference to the sacrificed rib or pad.

During normal operation the sacrificed rib 1 slides over the ground while the ordinary rib 2 does not slide over the ground. A measurement of the maximum grip potential on the ground is made by virtue of the sacrificed rib 1.

Inside each sacrificed rib or sacrificed pad, one or more sensors 3 enable the measurement of the deformations or stresses to which the rib or pad is subjected while the tyre is rolling, these being measured in the longitudinal and transverse directions. The stresses or deformations can also be measured in the vertical direction, and this improves the performance of the system.

With an appropriate sensor 3 these measurements can be obtained throughout the life of the tyre. It is of course desirable that the part of the tyre tread specifically involved in the measurement should be as small as possible, or more fundamentally, that it should not affect the tyre's performance adversely. For that reason, it may be advantageous to limit the part in question to one or a small number of rubber pads, or to limit it to a circumferential rib as narrow as possible. The information desired can be obtained by making a single measurement for each rotation of the tyre. As regards the vehicle, it seems superfluous to involve all its tyres in such measurements, and one tyre on each side would seem quite sufficient.

During free rolling (i.e. with no coupling to an engine nor any braking, with F_1 representing the rotation direction and F_2 the direction of movement) and when the tyre is rolling in a straight line along a road, when a point at the surface of a sacrificed rib comes in contact with the road a braking sheer stress σ_f develops at the interface between the sacrificed rib and the road (Fig. 2). This is added to the sinusoidal stress normally acting on all the ribs, an example of which is represented by the curve relating to the rib 2 in Fig. 3. The resultant stress on the sacrificed rib takes the form of the curve relating to the rib 1 in Fig. 3. This stress increases from the instant when contact begins until the instant when the shear stress reaches the maximum value permitted by the friction potential of the rubber against the ground.

Fig. 3 presents the theoretical case of a friction potential which is infinite or very large. It shows the longitudinal shear stresses (in daN/cm^2) in a sacrificed rib and the stresses in a normal rib adjacent to the sacrificed rib, in the area of contact, as a function of the distance "D" (in mm) between the edge of the contact area and the point considered. In this case, the absolute value of the shear stress increases until the instant when contact between the said point and the road ceases.

If the friction potential is not infinite, which is the case in reality, the point in question will slide on the road surface as soon as the shear stress reaches the maximum value permitted by the friction potential. For a more realistic case in which the friction potential equals 0.5, Fig. 4 shows the longitudinal stresses (in daN/cm^2) on a sacrificed rib and an ordinary rib adjacent thereto, in the area of contact, as a function of the distance "D" (in mm) between the edge of the contact area and the point considered. The signal representing the shear stress as a function of the distance travelled by the centre of the wheel is different from that shown in Fig. 3. The form of the signal, and more particularly its maximum value, are directly related to the friction potential.

If that potential evolves, the initial part of the stress signal shown as a function of the distance travelled (equal to the speed multiplied by the time that has passed since the instant of first contact with the road) changes only very little. In contrast, the final part of the signal is modified in proportion to the friction potential level. Thus, analysis of the shear stress signal exerted on the sacrificed rib gives information about the friction potential between the rib and the road,

which is itself directly correlated to the grip potential of the tyre on the road.

From a pre-established relation connecting the friction potential of the rib and the grip potential of the tyre, on the one hand, and a regular re-calibration procedure using for example the property by virtue of which the maximum grip potential of the tyre under all road conditions taken together does not change very much, it is possible to deduce the value of the tyre's grip potential from the value of the shear stress exerted on the sacrificed rib, or that of any signal representing the said shear stress. This re-calibration procedure is necessary because the pressure under the sacrificed rib can change progressively as the tyre becomes worn, for example as a function of the tyre wear, even under identical conditions of tyre load and inflation pressure, and this pressure evolution introduces a variable which modifies the relationship between the shear stress exerted on the rib and the tyre's grip potential.

If the sacrificed rib is additionally equipped to measure the vertical stress at the same point, the coefficient of friction between the rib and the ground can be calculated by finding the ratio between the shear stress and the vertical stress. In this case, there is no longer any need to re-calibrate regularly in order to evaluate the tyre's grip potential.

Accordingly, in an advantageous variant of the detection method, the stages required for the detection of a variation of the said first signal and for producing an estimate of the grip potential within the said tyre contact area comprise the following operations:

a) Production of a second signal representing a vertical force in the said contact surface of the first element.
b) Production from the first and second signals of a third signal representing the ratio between the tangential force and the vertical force.
c) Detection of a variation of the said third signal that characterises a loss of grip.
d) Production of an estimate of the friction potential in the said contact surface of the first element; and
e) From the friction potential, production of an estimate of the grip potential in the said tyre contact surface.

The braking stress that develops in the contact area results from the difference between the outer circumferences of the sacrificed rib and the adjacent ribs. Thus, by modifying this length difference, the rapidity with which the stress increases between the instants of entry into contact and its exit is changed: the larger the length difference, the more rapidly the shear stress increases.

If the tyre is rolling with a sideways drift angle, a transverse stress develops at the interface between the sacrificed rib and the road. This is vectorially added to the longitudinal stress. The resultant then undergoes the same evolution as that described earlier, namely in that its modulus increases between the instants when contact is established and when its value reaches the maximum permitted by the friction potential, provided that the difference between the lengths of the circumferences of the sacrificed rib and the adjacent ribs is sufficiently large.

In another advantageous application of the method, the following stages are also included:

a) Production of a first operational tread signal, which represents a tangential force in a contact surface zone of the said at least one second element.
b) Production of a second operational tread signal, representing a vertical force in a contact surface zone of the said at least one second element.
c) Production of an indication characterising the tangential force exerted on the tyre, by integration of the said first operational tread signal between the instants when contact between the road and the said zone begins and ends, across the width of the tyre.
d) Production of an indication characterising the vertical force exerted on the tyre, by integration of the said second operational tread signal between the instants when contact between the road and the said zone begins and ends, across the width of the tyre.
e) Determination of the "available grip margin" from the difference between the tyre's grip potential and the ratio between the said tangential and vertical forces exerted on the tyre.

This way of estimating the "available grip margin" entails estimating the vertical and tangential forces in the elements of the tread. Below, another method is explained which dispenses with that knowledge or these estimates.

Fig. 5 shows the longitudinal shear stresses (in daN/cm^2) in a sacrificed rib, in the area of

contact, as a function of the distance "D" (in mm) between the edge of the contact area and the point considered, in the case of rolling with a braking couple and a friction potential equal to 0.5 (curve A), in the case of free rolling and infinite friction potential (curve B), and in the case of free rolling and a friction potential equal to 0.5 (curve C). If an drive or braking couple is exerted on the tyre, a longitudinal stress is added to or subtracted from the stress induced by the length difference between the circumferences of the ribs. In the case of a braking couple, for example, the stress signal increases more rapidly as a function of the distance travelled than in the case when the wheel is running with no couple acting on it (Fig. 5).

Fig. 6 shows signals representing the longitudinal shear stresses (in daN/cm^2) as a function of the distance "D" (in mm) between the edge of the contact area and the point considered, developed under a sacrificed rib and along given ground, on the one hand in the case when a braking couple is applied (curve 1) and on the other hand during free rolling (curve 2). The points B1 and B2 are the points of the curves that correspond to an abrupt variation in the slopes of the curves. This abrupt variation represents a loss of grip (beginning of sliding) or a restoration of grip (end of sliding). The point A0 corresponds to the beginning of the contact area. It can be seen in Fig. 6 that the mean gradient of curve 1 between the point A0 and B1 is steeper in its absolute value than that of curve 2 between the points A0 and B2. This is because the available grip margin in the case corresponding to curve 1 is smaller than the available grip margin in the case corresponding to curve 2. The ratio between the said mean gradient and the value of the signal at the point characterising a loss of grip (respectively B1 and B2 on curves 1 and 2) is an example of an indicator of the available grip margin.

Accordingly, in a particular application of the method intended to produce an indication of the available grip margin without having to measure or estimate the vertical and tangential forces effectively acting on the tyre, the invention proposes that the function of the signal should be the ratio between the mean value of the first derivative of the said signal relative to the time and value of the signal at the point that characterises a loss of grip.

Considered in another way, it can be seen that the length of the segment A0-A1 is smaller than that of the segment A0-A2. This expresses the fact that the available grip margin in the case of curve 1, corresponding to the braking couple, is smaller than the available grip margin in the case of curve 2 corresponding to free rolling. Thus, the lengths of these segments provide

further information representing the available grip margin, since the said grip margin decreases as the length of the said segments becomes shorter.

Accordingly, in a particular application of the method intended to produce an indication of the available grip margin without having to measure or estimate the vertical and tangential forces effectively acting on the tyre, the invention proposes that the function of the signal should be the time interval separating the detections.

Thus, from an appropriate analysis of the stress signal represented as a function of the distance travelled, equal to the product of the speed and the time passing since the entry of the point where the measurement is effected into contact with the ground, information of two kinds can be obtained: information representing the grip potential between the tyre and the road, and information about the level of constraint (drive power, braking or transverse movement) exerted on the tyre, from which, therefore, the tyre's available grip margin can be determined.

Measurements of the longitudinal and transverse deformations of the rib can be used in the same way instead of measurements of the stresses. Simply, when it is desired to calculate the coefficient of friction, a prior correlation between the values of the deformations and stresses must be established and taken into account in the calculation.

All that has been described above for a sacrificed rib can also be applied in the case of a sacrificed pad.

With certain tyres it can be difficult to produce under the sacrificed rib a shear stress sufficiently high to cause the rib to slide on any type of ground surface and from the free rolling of the tyre, if the sacrificed rib is made from the same material as the adjacent ribs. During the wear of the tyre, the vertical contact pressure between the sacrificed ribs or pads and the ground may become very small because the initial wear of the sacrificed ribs or pads is more rapid than the wear of the tyre's other ribs or pads. This can have an adverse effect on the precision with which the grip potentials are determined when the sacrificed ribs or pads have reached a condition of wear in which the contact pressure is very low.

It is known that, disregarding the groove effect due to the tread pattern, the pressure exerted on

the ground in the contact area corresponds essentially to the nominal inflation pressure of the tyre. Now, by its very nature, the pressure under a sacrificed rib is only a fraction of the said inflation pressure. To be specific, it has been observed experimentally that the measurements proposed by the present invention give reliable results if the residual ground-contact pressure under the sacrificed rib (or more generally, the first element) preferably amount to at least 30% to 40% (and better still, at least 50%) of the nominal pressure.

Now, during free rolling and because of the phenomenon of rubber wear, an equilibrium is established such that the wear rates of the first and second elements are identical, so that the difference in height between the first and second elements is constant. At this equilibrium, a certain residual pressure is found under the sacrificed rib. If this residual pressure is too small (for example 10% of the nominal pressure), the measurements described in the present application cannot be made, or at least such measurements are not reliable because they are not representative of the grip prevailing under the ordinary elements (i.e. the non-sacrificed elements) of the tread. Accordingly, it is proposed to use for the sacrificed rib a modified material, so that the residual pressure will be sufficiently high. It has been verified experimentally that the measurement conditions are much better and the results are sufficiently representative of the grip conditions prevailing for unmodified materials.

Thus, in an embodiment of the present invention, the said first element (see rib 1 in Fig. 1) is made of a material different from that used to make the said second element, such that the said first element has better wear resistance than the said second element. In this way, despite the fact that by the nature of the invention the said first element is subjected to stresses prejudicial to its longevity, the said first element is kept in a condition appropriate for the estimation of the grip potential or grip margin.

A first variant for a tyre according to the invention concerns a tyre in which the said first element (see rib 1 in Fig. 1) is made of a material different from the material used to make the said second element, such that the said first element has a grip potential lower than the said second element. This has the advantage that the tangential stresses required to produce sliding of the sacrificed rib are reduced.

For example, at the tyre production stage a tread can be made by co-extrusion of the different

uncured rubbers appropriate for the purpose. The point of this measure is to allow these sacrificed elements to slide, against a given ground surface, at shear stresses lower than those that would be necessary if these elements consisted of the same materials as that of the tyre's other pads or ribs. Since the wear rate of a rubber element decreases very rapidly with decreasing shear stress between the contact area of the element and the ground, when the element slips along the ground, the consequence of this improvement is that the sacrificed ribs or pads made from the said material with less grip will wear away less quickly, and the vertical contact pressure between these sacrificed ribs or pads and the ground will also decrease less quickly during the wear of the tyre.

Another variant of the tyre according to the invention concerns a tyre in which the said first element is made of a material with higher Young's modulus than that of the material used for the said second element. The consequence of this is to increase the tangential stresses at the moment when sliding begins. This measure can be combined with the previous one.

For this reason, it is also proposed in another advantageous variant to make the said sacrificed ribs or pads of a material with better wear resistance than the material constituting the other ribs or pads of the tyre's tread pattern. The point of this measure is again to reduce the wear rate of the sacrificed ribs or pads, and consequently to achieve a less rapid decrease of the vertical contact pressure of the sacrificed ribs or pads during the wear of the tyre.

These three variants can be advantageously combined. This combination makes it possible throughout the life of the tyre to maintain a vertical contact pressure between the sacrificial ribs or pads and the ground, which is sufficiently high to ensure good precision of the grip potential measurements.

The tyre's grip potential on the road directly determines the maximum level of the steering, braking and drive-power forces that can be transmitted to the vehicle. It is a determinant factor of the vehicle's mobility and road-holding.

Statistical studies carried out in several countries show that there is indisputably a relation between this grip potential and the risk of accidents on wet roads: the lower the grip potential on a wet road, the higher is the risk of an accident. Thus, the safety of users is closely dependent on

the grip potential.

An important contribution to safety is to be able to evaluate the level of the grip potential of a tyre as early as possible before it reaches its grip limit, since the possibility of avoiding an accident in the case of insufficient grip will be the greater, the sooner action is taken to adapt the rolling conditions of the vehicle.

The design principle of the tyre presented here offers considerable advantage from this standpoint. In effect, it enables the level of the grip potential to be evaluated even when the tyre is rolling freely, which amounts to saying that the said potential can be determined under any vehicle rolling conditions, from the situation of rolling in a straight line at constant speed to situations of maximum braking and acceleration, or going round bends at the very limit of grip. Thus, the available grip potential can be evaluated continuously.

From the same measurements it is also possible to know what fraction of the grip potential is effectively being utilised.

The table below shows the applications permitted by knowledge of such information.

	ADDRESSEE OF THE INFORMATION		
INFORMATION OBTAINED	DRIVER	VEHICLE	OTHER USERS & TRAFFIC MANAGERS
GRIP POTENTIAL	• Warning of variations in the grip potential level • Comparison of the momentary potential with a statistical population of grip levels and warning of the position of that momentary potential relative to this population (high, moderate, low, very low level) •	• Adaptation of the driving strategy of the active systems (anti-lock, anti-skid, path control) • Assistance to the driver, correction of control commands when they seem inappropriate or when corrective action seems necessary in view of the vehicle's expected response	• Warning to other road users of the available grip level at all points of the road network (in association with a position detection system) • Provision to the bodies responsible for road network maintenance of real-time data allowing optimum management of road maintenance
AVAILABLE GRIP MARGIN	Warning to the driver of what fraction of the potential has been utilised and alerting him to the approach of the grip limit	Regulation of the active systems (anti-lock, anti-skid, path control)	Alerting those responsible for road network management about the points where the grip limit is most often approached.

From knowledge of the grip potential alone, or a datum directly correlated with the grip potential, it becomes possible:

- to inform the driver of the vehicle:
  - ⇨ when variations of the grip level occur: for example, if the potential decreases below a certain level of variation, an acoustic or visual signal can be triggered in order to warn the driver to adapt his driving and increase his vigilance;
  - ⇨ about the relative grip level available at a given instant compared with a statistical base of the grip levels encountered: this information, determined continuously when the vehicle is in motion, can be fed into a database implanted in a data processing system in the vehicle or outside it (a central database with which the vehicle communicates); moreover, this information can be compared with the statistical population already stored in the database to determine to which percentile of the said population it belongs; this result can be converted to a simple datum communicated to the driver (for example by the indication of a conventional level describing the grip available: high, moderate, low, very low);

- to act upon the vehicle:
  - ⇨ to adapt the control strategy of vehicle systems such as the wheel anti-locking, anti-skid and active path control systems: these systems could have different strategies depending on the grip level, which are predefined during manufacture; as a function of the momentary grip level, the most appropriate control strategy could be brought into play;
  - ⇨ to enable determination of the optimum control manoeuvres to be applied to a working element of the vehicle; numerical simulations in real time can now be carried out in vehicles; knowing the grip level, it is possible to look for the correct manoeuvre to be applied to a working element (for example the brakes) in order to elicit an optimum response; simulation can also be used to predict the vehicle's response to manoeuvres effected by the driver, and consequently to correct his manoeuvres or to provide assistance if they seem inappropriate;

- to inform other road users and the organisations responsible for road traffic management, by

communicating the data to central databases; the currently available means of communicating with and locating mobile units (the GPS system for example) enable any grip potential data emitted by a vehicle to be associated with a precisely identified stretch of road, and those data can then be transmitted to a central system; from such information it is possible:

- ⇨ to inform other road users and their vehicles of the grip level available at a given point before they have even reached the said point, so making it possible even earlier to anticipate the corrective action that may be necessary at the level of the vehicle controls;
- ⇨ to provide road traffic management organisations with precise statistical data in real time concerning the grip level, so rendering unnecessary the regular road grip measurements carried out in some countries to monitor their road network.

If this information on the available grip potential is supplemented with information on the grip level effectively utilised, it also becomes possible:

- to inform the driver about the degree to which this available potential has been used up and so to alert him if the grip limit is approaching;
- to regulate the vehicle systems (wheel anti-lock or anti-skid systems, for example) directly from the difference between the potential available and the potential already utilised;
- to provide those responsible for traffic management with statistical information enabling the detection of network points where the grip limit is most frequently approached and where the risk of accidents may consequently be high, even before that risk has been expressed in the form of accident statistics.

For example, a measurement can be carried out as explained in the patent DE 3937966 A1. For example, a magnetic element may be incorporated in a sacrificed pad or rib, at a point such that the element undergoes a displacement relative to Hall-effect sensors positioned in the tyre when the said sacrificed pad or rib is subjected to a tangential or normal force. The Hall-effect sensors are arranged so as to measure the displacement of the magnetic element at least under the action of a tangential force applied at the surface of the sacrificed pad or rib, or in addition and separately, to measure its displacement under the action of a normal force applied to the

sacrificed pad or rib.

As a variant, a measurement could also be carried out as described in the patents US 5 864 056 or US 5 502 433.

The signals so measured are sent to a computer which determines the grip potential and the available grip margin in accordance with one of the methods proposed. It should be noted that current technology enables the transmission, preferably the teletransmission of signals from one or more measurement units implanted in the tread, and the vehicle as such, which it is not the purpose of this invention to deal with except only from that standpoint, is relatively independent of the measurement aspects treated here.

The calculated data are themselves addressed for example to a device that enables the driver to be alerted, or they are sent, for example via a Hertzian route, to a system external to the vehicle that enables the grip potential data concerning the ground to be centralised and used to inform all road users, or they can be used to regulate systems or working units on the vehicle to which the tyre is fitted.

CLAIMS

1. Tyre whose tread comprises a first tread element (1) having a contact surface with the ground located a distance from the wheel axle smaller than that of at least one second element (2), the said elements being such that, during normal operation, the surfaces of the two elements come into contact with the ground in a contact area and being such that, at least within a range of rolling conditions to be monitored, the contact surface of the first element slides relative to the ground during its passage through the contact area, the said tyre comprising means that constitute a sensor within the said first element (1), the said means constituting a sensor being sensitive at least to a tangential force in the said contact surface of the said first element during its passage through the contact area.

2. Tyre according to Claim 1, in which the said first element (1) is made of a material different from that used to make the said second element (2), which confers on the said first element a grip potential lower than that of the said second element.

3. Tyre according to Claim 1, in which the said first element (1) is made of a material different from the material used to make the said second element (2), which confers on the said first element a wear resistance better than that of the said second element.

4. Tyre according to Claim 1, in which the said first element (1) is made of a material having a Young's modulus higher than the Young's modulus of the material used to make the said second element (2).

5. Method for the detection of a grip characteristic between a wheel with a deformable tread and a surface along which it is rolling, comprising the following stages:
   a) Provision of at least a first contact element (1) of the tread having a contact surface with the ground, positioned a distance from the wheel axle smaller than the distance of a ground contact surface of at least one second element (2), the offset between the said contact surfaces being such that during normal operation the surfaces of the two elements come into contact with the ground and, at least

within a range of rolling conditions to be monitored, the contact surface of the first element slides relative to the ground during its passage through the contact area;

b) Production of a first signal that represents a tangential force in the said contact surface of the element nearest the axle;

c) Detection of a variation of the said first signal, that characterises a loss of grip;

d) Production of an estimate of the friction potential in the said contact surface of the said first element;

e) Production of an estimate of the tyre's grip potential.

6. Detection method according to Claim 5, in which the stages intended to detect a variation of the said first signal and to produce an estimate of the tyre's grip potential comprises the following operations:

a) Production of a second signal representing a vertical force in the said contact surface of the said first element;

b) Production from the first and second signals of a third signal representing the ratio between the tangential and vertical forces;

c) Detection of a variation of the said third signal that characterises a loss of grip;

d) Production of an estimate of the friction potential in the said contact surface of the first element; and

e) From the friction potential, production of an estimate of the said tyre's grip potential.

7. Method according to either of Claims 5 or 6, which comprises in addition the following stages;

f) Production of a first operational tread signal representing a tangential force in a zone of the contact surface of the said at least one second element;

g) Production of a second operational tread signal representing a vertical force in a zone of the contact surface of the said at least one second element;

h) Production of an indication that characterises the tangential force applied to the tyre, by integration of the said operational tread signal between the instants when the contact of the said zone with the ground begins and ends, and across the full width of the tyre;

i) Production of an indication that characterises the vertical force applied to the tyre, by integration of the said second operational tread signal between the instants when the contact of the said zone begins and ends, and across the full width of the tyre;

j) Determination of the "available grip margin" as the difference between the tyre's grip potential and the ratio between the said tangential and vertical forces applied to the tyre.

8. Method for detecting a grip characteristic between a wheel with a deformable tread and a surface over which it is rolling, comprising the following stages:

a) Provision of at least a first contact element of the tread having a contact surface with the ground, positioned a distance from the wheel axle smaller than the distance of a ground contact surface of at least one second element (2), the offset between the said contact surfaces being such that during normal operation the surfaces of the two elements both come into contact with the ground;

b) Production of a first signal representing a tangential force in the zone of the contact surface of the said first element;

c) Detection in the said first signal of the instant when the said first element enters the contact area;

d) Detection in the said first signal of the instant when the first signal undergoes a variation that characterises a loss of grip; and

e) Production of an indication that characterises an available grip margin, from a function of the first signal between the instant when entry into the contact area is detected and the instant when the said characteristic variation is detected.

9. Detection method according to Claim 8, in which the said function of the first signal is the ratio between the mean value of the first derivative of the said signal relative to the time and value of the signal at the point that characterises a loss of grip.

10. Detection method according to Claim 8, in which the said function of the first signal is the time interval separating the said detections.